Indicator: Nonindigenous Species as Ecological Stressors in the Estuaries of Oregon and Washington (249R)

Nonindiginous species (NIS) are one of the greatest threats to aquatic ecosystems and can significantly impact local and regional economies (Lowe et al., 2004). The number of invasive species in estuaries of Washington and Oregon (including Puget Sound, Columbia Estuary, Coos Bay) is rising, and these areas can then become as sources of invasives to other locales and outward along other transportation routes. Coastal waters are particularly vulnerable to NIS transported in ballast water and introduced via aquaculture (PS Update, 2002). It is becoming apparent that NIS are capable of significantly impacting estuaries along the west coast, even though they are rarely addressed in routine monitoring studies. One limitation is the lack of standardized invasion metrics.

This indicator focuses on estuarine soft-bottom communities of the Columbian Biogeographic Province located along the Pacific Coast from Cape Mendocino, CA north to the mouth of the Strait of Juan de Fuca, WA. It is limited to sites with salinities >= 5 parts per thousand. The indicator is based on the percent abundance of NIS individuals, relative to the combined abundance of native and NIS individuals in a benthic grab sample.

The data for this indicator were collected by the Environmental Monitoring and Assessment Program using a probability sample covering the period 1999-2001 and by a special study focusing on minimally exposed estuaries (Nelson et al., 2004; Nelson et al., in review). Probability sampling provides unbiased estimates of the percent abundance of NIS in all estuaries in the study area, but because the data for the special study have not yet been statistically expanded, data for this indicator is based on stations sampled rather than area.

Reference levels for the indicator are based on observations in estuaries with minimal exposure to invasion (ballast water discharges and aquaculture of exotic oysters) within the Columbia Biogeographic Province. Three levels of invasion were assigned to the indicator: "minimal" or "reference" when NIS constituted 0-10% of the individuals; "moderately invaded" when NIS constituted 10-50% of the individuals; and "highly invaded" when NIS were more abundant than the native species (>50% NIS).

What the Data Show

Approximately 15% of the stations in the Columbian Province were highly invaded (abundance of NIS > abundance of natives) and another 20% were moderately invaded (Figure 249-1). The study showed that nonindigenous species were among the most frequently occurring anthropogenic stressors in this biogeographic region when compared to indicators of sediment contamination or eutrophication (Nelson et al., 2004).

The extent of invasion was not uniform, however. Estuaries with greater exposure to shipping ballast water and aquaculture were more invaded: 44% of the stations in the estuaries exposed to these invasion vectors were moderately to highly invaded, compared to only 20% of the stations in estuaries with no or minimal exposure to these vectors (Figure 249-2). Nonetheless, the observation that 20% of the stations in these "pristine" estuaries were at least moderately invaded indicates that non-native species can disperse widely once they are introduced into a region, so even estuaries with no direct exposure to ballast water or aquaculture are at risk of invasion.

Indicator Limitations

- Studies in the San Francisco Estuary (Lee et al., 2003) and in Willapa Bay (Ferraro and Cole, in progress) have shown that the percent of NIS can vary substantially among communities., e.g. hard bottom versus sea grass beds. Reference points for Washington and Oregon estuaries as a whole may not be appropriate for specific community types.
- This indicator represents percent NIS in individual benthic grabs, but does not characterize the total number of NIS in the estuaries; it also does not include fish or other NIS not subject to benthic grab sampling.
- The invasion metrics are structural indicators; further research is needed to understand the relationship between these structural changes and impacts on ecosystem function.

Data Sources

EMAP Coastal Assessments 1999, 2000, 2001.
http://www.epa.gov/emap/html/pubs/docs/groupdocs/symposia/symp2004/Abstracts/Poster/lee.html

References

Lee II, Henry, B. Thompson, and S. Lowe. 2003. Estuarine and scalar patterns of invasion in the soft-bottom benthic communities of the San Francisco Estuary. Biological Invasions 5:85-102.

Lowe, S., Browne, M., Boudjelas, S., and M. De Poorter. November, 2004. 100 of the World's Worst Invasive Alien Species – A Selection from the Global Invasive Species Database. Published by the Invasive Species Specialist Group (ISSG) of the World Conservation Union (IUCN).

Nelson, W.G., H. Lee II, J.O. Lamberson, V. Engle, L. Harwell, and L.M. Smith. 2004. Condition of Estuaries of the Western United States for 1999: A Statistical Summary. EPA.620/R-04/200, U.S. Environmental Protection Agency, Washington DC.

Nelson, W.G., H. Lee II, and J. Lamberson. (in review). Condition of Estuaries of California for 1999: A Statistical Summary. U.S. EPA Report.

Puget Sound ActionTeam, 2002. Puget Sound Update; the Eighth Report of the Puget Sound Ambient Monitoring Program (PSAMP).

**Figure 249-1: Percent of Stations Falling into % NIS Abundance Classes -
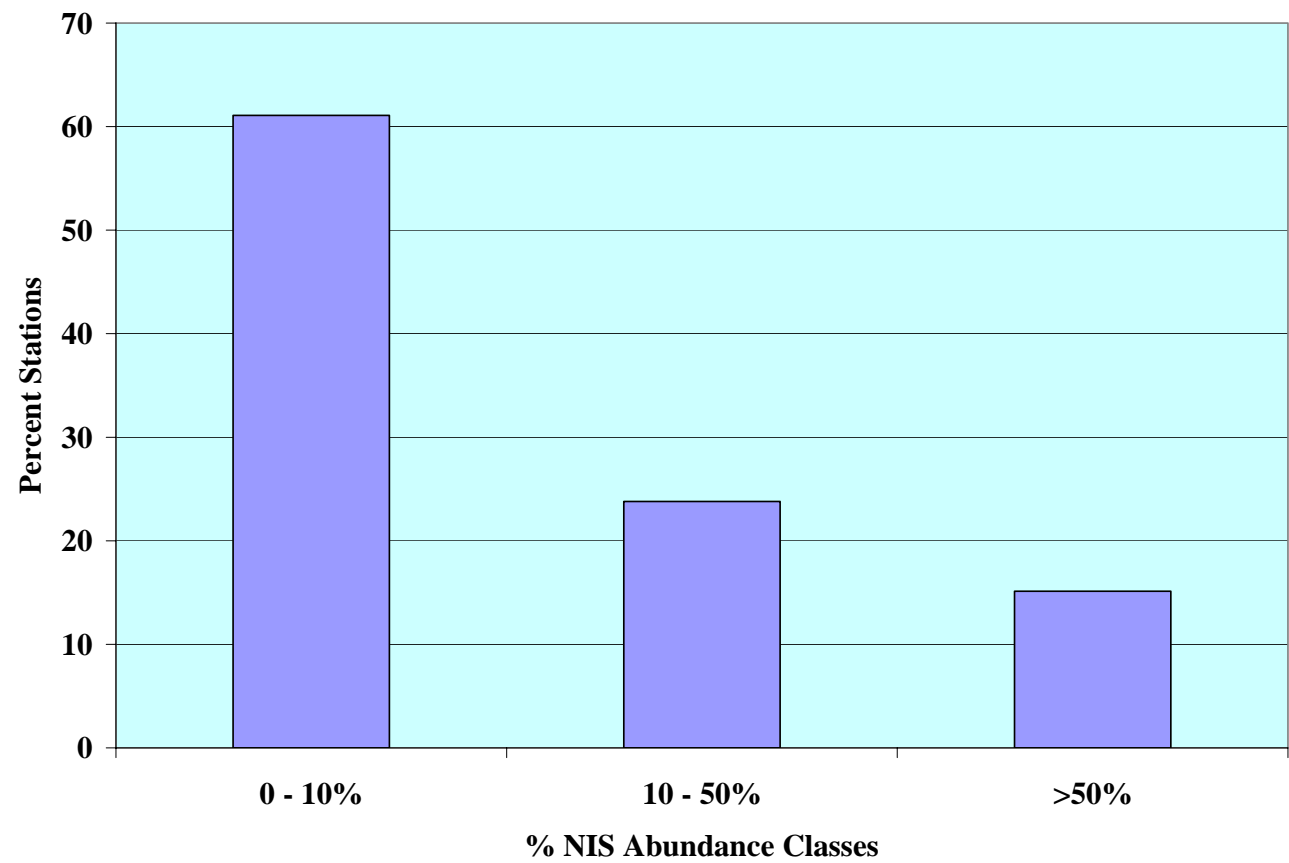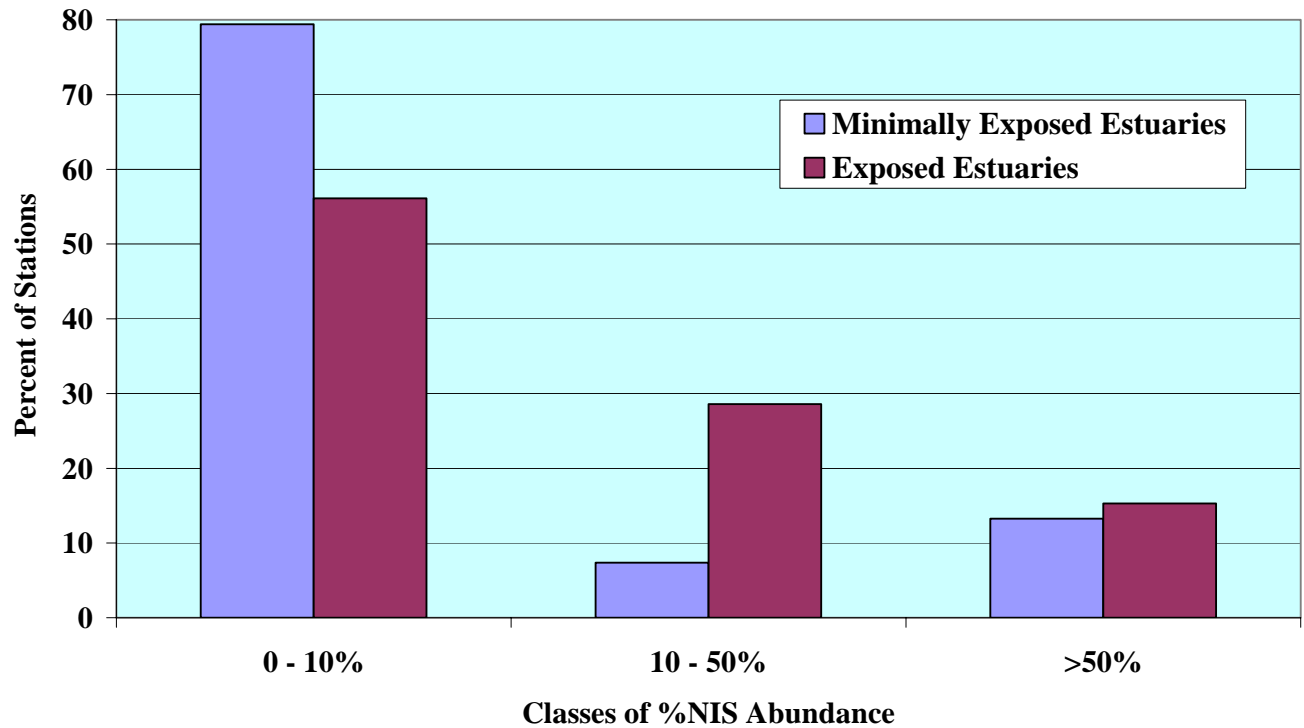EMAP 1999**

Figure 249-2: Benthic Index of Estuarine Nonindigenous Species (NIS): Percent of stations in Columbia Biogeographic Province falling into three levels of invasion based on the relative abundance of NIS for 'Minimally exposed" and "Exposed" estuaries.

R.O.E. Indicator QA/QC

Data Set Name: NON-INDIGENOUS SPECIES IN THE ESTUARIES OF OREGON AND WASHINGTON
Indicator Number: 249R (114765)
Data Set Source: Coastal Environmental Monitoring and Assessment Program (EMAP) data from estuaries of OR and WA.
Data Collection Date: 1999-2000,2002
Data Collection Frequency: 1/yr-1/2yr (irregular)
Data Set Description: Non-Indigenous Species in the Estuaries of Oregon and Washington as an Indicator of Ecological Stress.
Primary ROE Question: What are the trends in the diversity and biological balance of the Nation's ecological systems?

Question/Response

T1Q1 Are the physical, chemical, or biological measurements upon which this indicator is based widely accepted as scientifically and technically valid?

Yes. Standard EMAP protocols are used for sample collection, handling, and analysis, including standardized taxonomy for both the Washington and Oregon collections. These protocols are described in "U.S. EPA, 2001. National Coastal Assessment: Quality Assurance Project Plan 2001-2004. EPA/620/R-01/002" and "Nelson, et al., 2004. Condition of Estuaries of the Western United States for 1999: A Statistical Summary. EPA/620/R-04/200".

T1Q2 Is the sampling design and/or monitoring plan used to collect the data over time and space based on sound scientific principles?

Yes. The data presented is from Washington, Oregon, and Northern California collected under the Environmental Monitoring and Assessment Program (EMAP). The purpose of EMAP is to estimate the current status and trends in the condition of nation's ecological resources. The coastal component of EMAP creates an integrated coastal monitoring program along the west coast by taking water column measurement in conjunction with information about sediment characteristics and chemistry, benthic organisms (including nonindigenous species or NIS), fish to describe the current estuarine condition. EMAP is designed in such a way to provide a valid estimate for the entire resource of interest, in this case the small estuaries of Oregon and Washington. The data are collected using the Coastal EMAP protocols developed by EPA's Office of Research and Development. The QA plan and protocol(U.S. EPA, 2001. National Coastal Assessment: Quality Assurance Project Plan 2001-2004. EPA/620/R-01/002) is available at http://www.epa.gov/emap/nca/html/docs/qaprojplan.html while a description of the Coastal EMAP project in Region 10 is available at http://www.epa.gov/r10earth/emap.htm.

T1Q3 Is the conceptual model used to transform these measurements into an indicator widely accepted as a scientifically sound representation of the phenomenon it indicates?

The first cut at developing invasion metrics will be limited to those that can be derived from the benthic abundance/composition within individual benthic grabs (point scale). This is considered an exploratory effort, and other indices at this or additional spatial scales (e.g., entire estuaries) and with different target organisms (e.g., fishes) need to be evaluated in the future. The sites were selected using the EMAP probability design to represent that estuaries of Oregon and Washington with known levels of confidence.

T2Q1 To what extent is the indicator sampling design and monitoring plan appropriate for answering the relevant question in the ROE?

There are many stressors that influence the ecological condition of estuarine waters Non-indigenous species is one of theses stressors, but it is rarely addressed in state or regional monitoring studies. The ROE provides a methodical line of inquiry into the status, condition, and future trends for this non-indigenous species indicator. The examples of regional indicators allows the highlight of smaller scales - which is likely to have relevance to many audiences interested in the primary question of Ecological condition of estuaries regarding diversity and balance of species.

T2Q2 To what extent does the sampling design represent sensitive populations or ecosystems?

While estuaries can themselves be considered sensitive ecosystems, the sampling sites were randomly selected using the EMAP probability design. The samples are intended to represent the estuaries of Oregon and Washington, with known levels of confidence. The relative percentage of stations sampled in small estuaries of Washington and Oregon found to contain various types of environmental stressors at levels of some significance is depicted in data figure 249-2. The indicators shown were selected due to their importance as strtessors on the health of estuaries which are generally recognized as sensitive and highly valued ecosystems.

T2Q3 Are there established reference points, thresholds or ranges of values for this indicator that unambiguously reflect the state of the environment?

The most basic and unambiguous reference point for invasive species is their absence, which the invasive indices capture (Figure 249-2). However, invasion is not totally an "all-or-none" phenomenon as the extent of invasion can have direct management implications, and the two indices capture two different but complementary aspects of the extent of an invasion. The %NIS Abundance index is a measure of the current alteration in the benthic community due to invasions. The %NIS Species index is both as a measure of change in community structure and a measure of the potential risk of future changes in benthic community structure. The %NIS Species might also be viewed as an exposure measure for invasion vectors. These indices can be used to be used to assess the extent of invasion within classes of estuaries (Figure 249-1) or across a region (Figure 249-2), with the objective of prioritizing among estuaries or of assessing the importance of various invasion vectors. Additionally, by determining how these indices change over time, they can be used as performance measures to determine if the extent (or rate) of invasion is changing in response to management practices (e.g., ballast water management) or changes in the ecosystem condition (e.g., increased eutrophication, flow diversions).

T3Q1 What documentation clearly and completely describes the underlying sampling and analytical procedures used?

Lee, H., et al. 2003. Estuarine and scalar patterns of invasion in the soft bottom benthic communities of the San Frnacisco Estuary. Biological Invasions 5: 85-102, 2003.

T3Q2 Is the complete data set accessible, including metadata, data-dictionaries and embedded definitions or are there confidentiality issues that may limit accessibility to the complete data set?

Benthic data are available for 21 small estuaries and 9 large estuaries, with the number of grabs ranging from 1 to 28 per estuary (>5 ppt). Henry Lee, U.S. EPA ORD, NHEERL, Western Ecology Division, Newport Lab. (541) 867-5001 "Nelson, et al., 2004. Condition of Estuaries of the Western United States for 1999: A Statistical Summary. EPA/620/R-04/200."

T3Q3 Are the descriptions of the study or survey design clear, complete and sufficient to enable the study or survey to be reproduced?

Yes. While there are no standardized invasion metrics to assess the extent or patterns of invasion of aquatic ecosystems or bio-geographic regions, this effort proposes invasion indices for estuarine soft-bottom communities along the Pacific Coast of Northern California, Oregon, and Washington. The

first cut at developing such invasion metrics will be limited to those that can be derived from the benthic abundance and composition within individual benthic grabs (point scale). These indices capture the relative abundance of species of non-indigenous species (NIS) of soft-bottom organisms compared to the native species - at the spatial scale of a single benthic grab sample. The approach is reproducable.

T3Q4 To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

The data are collected using the Coastal EMAP protocols developed by EPA s Office of Research and Development. The QA plan and protocol (U.S. EPA, 2001. National Coastal Assessment: Quality Assurance Project Plan 2001-2004. EPA/620/R-01/002) is available at http://www.epa.gov/emap/nca/html/docs/qaprojplan.html.

T4Q1 Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

Yes. The probabilistic sampling design used in EMAP generates statistically unbiased estimates of the condition of estuaries. Additionally, a discussion of the scalar properties of the invasion indices can be found in: Lee, H., et al. 2003. Estuarine and scalar patterns of invasion in the soft bottom benthic communities of the San Frnacisco Estuary. Biological Invasions 5: 85-102, 2003.

T4Q2 Are uncertainty measurements or estimates available for the indicator and/or the underlying data set?

Yes. The data are collected using the Coastal EMAP protocols developed by EPA s Office of Research and Development. The QA plan and protocol is available at http://www.epa.gov/emap/nca/html/docs/qaprojplan.html, while the specifics of the 1999 sampling program are available in "Nelson, et al., 2004. Condition of Estuaries of the Western United States for 1999: A Statistical Summary. EPA/620/R-04/200". Additional information can be provided by Henry Lee, U.S. EPA ORD, NHEERL, Western Ecology Division, Newport Lab. (541) 867-5001

T4Q3 Do the uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

Not likely. Studies in the San Francisco Estuary (Lee et al., 2003) and in Willapa Bay (Ferraro and Cole, in progress) have shown that the percent of NIS can vary substantially among community or habitat types. Thus, the values of the indices, in part, reflect the specific communities sampled (e.g., seagrass bed vs. sand shrimp bed). However, since both the EMAP and small estuary studies used probabilistic sampling, the case can be made that they sampled community types in approximate proportion to their areal extent, and thus are an accurate estimate of invasion within each estuary or estuary class.

T4Q4 Are there limitations, or gaps in the data that may mislead a user about fundamental trends in the indicator over space or time period for which data are available?

Studies in the San Francisco Estuary (Lee et al., 2003) and in Willapa Bay (Ferraro and Cole, in progress) have shown that the percent of NIS can vary substantially among communities.Thus invasion reference or cut-points developed for an entire estuarine ecosystem may not be appropriate for a specific habitat (e.g., seagrass community). The indicators assess the extent of invasion at the point scale (i.e., benthic grab), which does not necessarily represent the extent of invasion within an entire community or estuary. That is, the indices do not directly measure the total number of nonindigenous species found within an estuary. Determining the statistical and functional relationships between local measures of invasion (as measured by these indices) and estuarine- or regional-scales of invasion is one possible future avenue in the development/validation of invasion

indicators. The invasion metrics are structural indicators; further research is needed to understand the relationship between these structural changes and impacts on ecosystem function. Determining such relationships is another possible future avenue in the development/validation of invasion indicators.